5189. (amended) The method of claim 704, further comprising providing heat from heaters to at least a portion of the formation, wherein the heaters are located in the formation in a unit of heaters, and wherein the unit of heaters comprises a triangular pattern.

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5190. (amended) The method of claim 704, further comprising providing heat from heaters to at least a portion of the formation, wherein the heaters are located in the formation in a unit of heaters, wherein the unit of heaters comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

Response To Office Action Mailed January 31, 2003

A. Pending Claims

Claims 531-556, 558-610, 623-625, 665-706, and 5150-5190 are currently pending. Claims 531-537, 539, 541, 554, 558, 560, 562, 564, 565, 568-570, 573-579, 581, 583, 595, 598, 600, 602, 604, 605, 608-610, 623, 665-674, 676, 678, 690, 693, 695, 696, 698, 702-704, 5150-5161, 5163, 5165, 5177, 5180, 5182, 5183, 5185, 5186, 5189, and 5190 have been amended. Claims 532-537, 539, 541, 554, 558, 560, 562, 564, 565, 568-570, 573-579, 581, 583, 595, 598, 600, 602, 604, 605, 608-610, 623, 665-674, 676, 678, 690, 693, 695, 696, 698, 702-704, 5150-5161, 5163, 5165, 5177, 5180, 5182, 5183, 5185, 5186, 5189, and 5190 have been amended for clarification and/or correction of typographical errors. Claim 557 has been cancelled.

B. Submission of Corrected Formal Drawings

In the Office Action mailed January 31, 2003, the Examiner indicated approval of the proposed drawing corrections filed on March 12, 2002. Applicant herewith submits the corrected formal drawings approved by the Examiner (7 sheets, including FIGS. 23a, 23b, 32, 44, 54, 55, 59, 60, and 63).

C. Information Disclosure Statements

Applicant has not received signed, initialed Forms PTO-1449 (references A1-A256 and B1) submitted with the Information Disclosure Statement mailed on December 18, 2001 (postcard date stamped received by the USPTO on January 3, 2002) and Forms PTO-1449 (references A257-A348) submitted with the Information Disclosure Statement mailed on December 18, 2001 (postcard date stamped received by the USPTO on January 3, 2002). Applicant respectfully requests signed, initialed copies of the above-mentioned Forms PTO-1449. Copies of the originally filed Forms PTO-1449 noted above are enclosed for the Examiner's convenience.

D. The Specification Does Not Lack Proper Antecedent Basis For The Claimed Subject Matter

In the Office Action, the Examiner objected to the Specification as failing to provide antecedent basis for the claimed subject matter of claims 571 and 572.

In item 2 of the Office Action, the Examiner states: "The specification is objected to as failing to provide proper antecedent basis for the claimed subject matter. See 37 CFR 1.75(d)(1) and MPEP § 608.01(o). Correction of the following is required: No antecedent basis can be found in the specification for the specific pressure-temperature relationship formulas set forth in claims 571 and 572."

Applicant submits that original claims 571 and 572 constitute their own description. (See

In re Koller, 613 F.2d 819, 204 USPQ 702 (CCPA 1980); *accord In re Gardner*, 475 F.2d 1389, 177 USPQ 396 (CCPA 1973); *accord In re Wertheim*, 541 F.2d 257, 191 USPQ 90 (CCPA 1976).) With regard to 37 CFR 1.75(d)(1) and MPEP § 608.01(o), Applicant submits that claims 571 and 572 conform to the invention as set forth in the remainder of the Specification and the terms and phrases used in the claims find clear support and/or antecedent basis in the description so that the meaning of the terms in the claims are ascertainable by reference to the description. To expedite the case, Applicant has amended the Specification to include the values of A, B, and API gravity recited in claims 571 and 572, as well as values cited in original claims 570, 623-625, 666-668, and 704-706. Applicant respectfully requests removal of the rejections of claims 571 and 572.

E. Provisional Double Patenting Rejection

The Examiner provisionally rejected claims 531-609 under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims of copending U.S. Patent Application Nos.:

09/840,936; 09/840,937; 09/841,000; 09/841,060; 09/841,061; 09/841,127; 09/841,128; 09/841,129; 09/841,130; 09/841,131; 09/841,170; 09/841,193; 09/841,194; 09/841,195; 09/841,238; 09/841,239; 09/841,240; 09/841,283; 09/841,284; 09/841,285; 09/841,286; 09/841,287; 09/841,288; 09/841,289; 09/841,290; 09/841,291; 09/841,292; 09/841,293; 09/841,294; 09/841,295; 09/841,296; 09/841,297; 09/841,298; 09/841,299; 09/841,300; 09/841,301; 09/841,302; 09/841,303; 09/841,304; 09/841,305; 09/841,306; 09/841,307; 09/841,308; 09/841,309; 09/841,310; 09/841,311; 09/841,312; 09/841,429; 09/841,431; 09/841,432; 09/841,433; 09/841,434; 09/841,435; 09/841,436; 09/841,437; 09/841,438; 09/841,439; 09/841,440; 09/841,441; 09/841,442; 09/841,443; 09/841,444; 09/841,445; 09/841,446; 09/841,447; 09/841,448; 09/841,449, 09/841,488; 09/841,489; 09/841,490; 09/841,491; 09/841,492; 09/841,493; 09/841,494; 09/841,495; 09/841,496; 09/841,497; 09/841,498; 09/841,499; 09/841,500; 09/841,501; 09/841,502; 09/841,632; 09/841,633; 09/841,634; 09/841,635; 09/841,636; 09/841,637; 09/841,638; and 09/841,639.

Applicant respectfully traverses the provisional double patenting rejection. Applicant respectfully submits that the omnibus nature of this rejection does not provide Applicant with sufficient detail in which to address such rejection. Applicant also respectfully submits that the rejection is also inconsistent with certain restrictions issued in the above-referenced cases.

Applicant respectfully requests reconsideration.

Pursuant to discussion with the Examiner, for the convenience of the Examiner, Applicant will forward copies of allowed claims for the above-referenced cases to the Examiner's Supervisor. Applicant understands that the Examiner's Supervisor will review the allowed claims for the above-referenced cases and then reconsider the double patenting rejection in view of such allowed claims.

The Examiner specifically provisionally rejected claims 531-609 under the judicially created doctrine of obviousness-type double patenting as being unpatentable over copending U.S. Patent Application No. 09/841,437. Upon issuance of a patent for U.S. Patent Application No. 09/841,437 or the present application, or upon both applications being in condition for allowance but for the provisional double patenting rejection, Applicant will provide arguments for the inappropriateness of the double patenting rejection and/or provide a terminal disclaimer for the patent and/or patent applications.

F. The Claims Are Not Anticipated By Ljungstrom Pursuant To 35 U.S.C. § 102(b), or in the Alternative, Are Not Obvious Over Ljungstrom Pursuant To 35 U.S.C. § 103(a)

The Examiner rejected claims 531-534, 540, 542-553, 555, 556, 564, and 565 under 35 U.S.C. 102(b) as anticipated by or, in the alternative, obvious under 35 U.S.C. 103(a) over U.S. Patent No. 2,923,535 to Ljungstrom (hereinafter "Ljungstrom"). Applicant respectfully disagrees with these rejections.

The standard for "anticipation" is one of fairly strict identity. To anticipate a claim of a patent, a single prior source must contain all the claimed essential elements. *Hybritech, Inc. v. Monoclonal Antibodies, Inc.*, 802 F.2d 1367, 231 U.S.P.Q.81, 91 (Fed.Cir. 1986); *In re Donahue*, 766 F.2d 531, 226 U.S.P.Q. 619, 621 (Fed.Cir. 1985). To establish *prima facie*

obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981 (CCPA 1974), MPEP § 2143.03.

In order to reject a claim as obvious, the Examiner has the burden of establishing a *prima facie* case of obviousness. *In re Warner et al.*, 379 F.2d 1011, 154 U.S.P.Q. 173, 177-178 (C.C.P.A. 1967). To establish a *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981, 180 U.S.P.Q. 580 (C.C.P.A. 1974), MPEP § 2143.03.

The Examiner states:

> Ljungstrom discloses a process for heating a coal or oil shale formation utilizing one or more heaters (22) wherein the heat imparted causes volatilization, pyrolysis and/or gasification of hydrocarbon constituents, which are subsequently produced to the surface as production fluids or "mixture" comprising condensable hydrocarbons. Ljungstrom specifically discloses that the temperature "may be controlled depending on ... the pressure maintained or permitted to build up" (col. 2, lines 41-45). In addition, the temperature and pressure curves of Figures 10 and 11 appear to indicate a direct relationship between temperature and pressure within the coal formation. Thus, Ljungstrom inherently or obviously controls the temperature in the formation as function of pressure, as called for in claim 531.

Ljungstrom states: "During the ordinary production conditions the gases and vapors build up a certain superpressure in the shale. The pressures at different points are shown in Table 1 and Figure 12." (Ljungstrom, col. 2, lines 41-45)

Ljungstrom also states:

> All gas outlet valves were then closed. As heat was supplied continuously, gases and vapors were still formed. The only way for the flow of the product out of the shale then was a diffusion towards the surroundings in all directions. When the pressures were measured at the same test points as above it was found that the superpressure in the shale had increased, as shown in Table 2 and Figure 12. (Ljungstrom, col. 5, lines 29-36)

The above referenced Tables 1 and 2 and Figure 12 of Ljungstrom display pressures ranging from 0.00 to 0.75 atm.

Independent claim 531 has been amended to include the features of claim 557. Amended claim 531 describes a combination of features including: "maintaining the controlled pressure of at least about 2.0 bars absolute". Ljungstrom appears to teach or suggest the production of gases and vapors at field pressures at or below about 0.75 atm. Ljungstrom does not appear to teach or suggest at least the above-quoted feature of claim 531. Applicant respectfully requests removal of the rejection of claim 531 and the claims dependent thereon.

If an independent claim is nonobvious under 35 U.S.C. 103, then any claim depending therefrom is nonobvious. *In re Fine*, 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988). Applicant submits that, in addition, many of the claims dependent on claim 531 are separately patentable.

The Examiner states:

> Regarding claims 542-553, 555 and 556, it is deemed that the myriad hydrocarbon product mixtures recited in these claims would necessarily or obviously occur in carrying out the heating process of Ljungstrom, i.e., the precise composition of the product fluids is seen as dictated by the type of coal or oil shale naturally occurring in the particular hydrocarbon formation actually encountered in the field. Moreover, it would be an obvious matter of choice to operate the Ljungstrom process to minimize what would be considered refinery contaminants, such as sulfur, nitrogen and/or oxygen in the product mixtures. Similarly, it would be obvious to reduce or minimize the amount of asphaltenes in the product mixtures for optimum downstream refining. Also, in the event that the particular coal deposit encountered yields ammonia gas, it would be an obvious expedient to utilize it in a commercial process such as fertilizer production.

The fact that a certain result or characteristic may occur or be present in the prior art is not sufficient to establish the inherency of that result or characteristic. *In re Rijckaert*, 9 F.3d 1531, 1534, 28 USPQ2d 1955, 1957 (Fed. Cir. 1993). "To establish inherency, the extrinsic evidence 'must make clear that the missing descriptive matter is necessarily present in the thing

described in the reference, and that it would be so recognized by persons of ordinary skill. Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of circumstances is not sufficient.'" *In re Robertson,* 169 F.3d 743, 745, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999). In relying upon the theory of inherency, the Examiner must provide a basis in fact and/or technical reasoning to reasonably support the determination that the allegedly inherent characteristic necessarily flows from the teachings of the applied prior art. *Ex parte Levy,* 17 USPQ2d 1461, 1464 (Bd. Pat. App. & Inter. 1990).

Applicant submits that the product mixtures recited in claims 542-553, 555, and 556 would not necessarily or obviously be producible by carrying out the heating process of Ljungstrom. The product mixtures recited in claims 542-553, 555, and 556 may be produced by controlling and/or modifying formation conditions during treatment to produce the selected results recited in the claims. Applicant respectfully requests removal of the rejections of claims 542-553, 555, and 556.

The Examiner states: "The heating process of Ljungstrom also causes an increase in permeability of the hydrocarbon formation (note col. 2, lines 1-24). It is further deemed that such permeability increase will inherently or obviously be substantially uniform, as called for in claim 565, e.g. during an overall field heating process, as illustrated in Figures 2-5. Such permeability increase is deemed to necessarily or inherently encompass an increase to 'greater than about 100 millidarcy', as called for in claim 564; alternatively, to increase the permeability to greater than 100 millidarcy would have been an obvious matter of choice in order to ensure adequate fluid flow through the formation."

Ljungstrom states: "The pressure distribution around the zone, where the pressure is created (by chemical reactions), was measured. The pressure drop was different in different directions, showing a different porosity and permeability for the gas flow." (Ljungstrom, col. 5, lines 56-60)

Amended claim 564 describes a combination of features including: "wherein allowing the heat to transfer increases a permeability of a majority of the part of the formation to greater than about 100 millidarcy." Amended claim 565 describes a combination of features including: "wherein allowing the heat to transfer increases a permeability of a majority of the part of the formation such that the permeability of the majority of the part of the formation is substantially uniform."

Ljungstrom appears to teach or suggest different permeabilities in the formation depending on the extent of chemical reaction. Ljungstrom does not appear to teach or suggest at least the above-quoted features of claim 564 and 565. Applicant respectfully requests removal of the rejections of claims 564 and 565.

G. The Claims Are Not Obvious Over Ljungstrom Pursuant To 35 U.S.C. § 103(a)

The Examiner rejected claims 539, 541, 560, 566, and 567 under 35 U.S.C. 103(a) as obvious over Ljungstrom. Applicant respectfully disagrees with these rejections.

In item 9 of the Office Action, the Examiner states: "The precise heating rate recited in claim 539 is deemed obvious matters of choice or design, especially in carrying out the embodiment in Ljungstrom of controlling and/or maintaining the temperature in the coal formation within a specific operating range (col. 2, lines 25-48)."

Amended claim 539 describes a combination of features including: "wherein heating energy/day (*Pwr*) provided to the selected volume is equal to or less than $h*V*C_v*\rho_B$, wherein ρ_B is formation bulk density, and wherein an average heating rate (h) of the selected volume is about 10 °C/day." Applicant submits that Ljungstrom does not appear to teach or suggest using a desired heating rate to calculate a maximum average heating energy/day to be applied to a selected volume of a formation. Applicant respectfully requests removal of the rejection of claim 539.

The Examiner states: "The thermal conductivity recited in claim 541 is deemed an obvious matter of choice or design based on, e.g., the quality and type of the coal formation present and/or the matrix characteristics of the particular coal formation encountered in the field."

Amended claim 541 describes a combination of features including: "wherein allowing the heat to transfer from the one or more heaters increases a thermal conductivity of at least a portion of the part of the formation to greater than about 0.5 W/(m ºC)." Applicant submits that allowing heat to transfer from the one or more heaters to increase a thermal conductivity of a portion of a formation to greater than about 0.5 W/(m °C) is unexpected based on literature in the art. For example, Applicant's Specification states:

> Certain embodiments described herein will in many instances be able to economically treat formations that were previously believed to be uneconomical. Such treatment will be possible because of the surprising increases in thermal conductivity and thermal diffusivity that can be achieved with such embodiments. These surprising results are illustrated by the fact that prior literature indicated that certain coal formations exhibited relatively low values for thermal conductivity and thermal diffusivity when heated. For example, in government report No. 8364 by J. M. Singer and R. P. Tye entitled "Thermal, Mechanical, and Physical Properties of Selected Bituminous Coals and Cokes," U.S. Department of the Interior, Bureau of Mines (1979), the authors report the thermal conductivity and thermal diffusivity for four bituminous coals. This government report includes graphs of thermal conductivity and diffusivity that show relatively low values up to about 400 °C (e.g., thermal conductivity is about 0.2 W/(m ºC) or below, and thermal diffusivity is below about 1.7 x 10^{-3} cm^2/s). This government report states that "coals and cokes are excellent thermal insulators."
>
> In contrast, in certain embodiments described herein coal may be treated such that the thermal conductivity and thermal diffusivity are significantly higher (e.g., thermal conductivity at or above about 0.5 W/(m ºC) and thermal diffusivity at or above 4.1 x 10^{-3} cm^2/s) than would be expected based on previous literature such as government report No. 8364. If treated as described in certain embodiments herein, coal does not act as "an excellent thermal insulator." Instead, heat can and does transfer and/or diffuse into the formation at significantly higher (and better) rates than would be expected according to the literature, thereby significantly enhancing economic viability of treating the formation. (Specification, p. 136, lines 8-29).

Thus, Applicant submits that allowing heat to transfer from one or more of the heaters to increase

a thermal conductivity of at least a portion of the part of the formation to greater than about 0.5 W/(m ºC) is not an obvious matter of choice or design. Applicant respectfully requests removal of the rejection of claim 541.

The Examiner states: "The steps of claims 560 and 566, such as controlling the heat or pressure in the formation, are deemed obvious matters of choice or design in carrying out the process of Ljungstrom, consistent with one of the overall objectives of Ljungstrom to control the heating process (col. 2, lines 25-55)." Applicant respectfully disagrees that the steps of claims 560 and 566 are obvious matters of choice or design.

Amended claim 560 describes a combination of features including: "altering a pressure in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than about 25." Claim 566 describes a combination of features including: "controlling the heat to yield greater than about 60 % by weight of condensable hydrocarbons, as measured by Fischer Assay."

Applicant submits that controlling and/or altering the pressure or heat as recited in claims 560 and 566 provides improved and/or unexpected results based on the prior art. For example, Applicant's Specification states:

> Controlling pressure, heat and/or heating rates of a selected section in a formation may increase production of selected formation fluids. For example, the amount and/or rate of heating may be controlled to produce formation fluids having an American Petroleum Institute ("API") gravity greater than about 25. Heat and/or pressure may be controlled to inhibit production of olefins in the produced fluids.
>
> Controlling formation conditions to control the pressure of hydrogen in the produced fluid may result in improved qualities of the produced fluids. In some embodiments it may be desirable to control formation conditions so that the partial pressure of hydrogen in a produced fluid is greater than about 0.5 bar absolute, as measured at a production well. (Specification, p. 13, line 28 - p. 14, line 7).

Applicant's Specification further discloses:

In an embodiment, a pressure within a heated portion of the formation may surprisingly increase the quality of relatively high quality pyrolyzation fluids, the quantity of relatively high quality pyrolyzation fluids, and/or vapor phase transport of the pyrolyzation fluids within the formation. Increasing the pressure often permits production of lower molecular weight hydrocarbons since such lower molecular weight hydrocarbons will more readily transport in the vapor phase in the formation. Generation of lower molecular weight hydrocarbons (and corresponding increased vapor phase transport) is believed to be due, in part, to autogenous generation and reaction of hydrogen within a portion of the coal formation. For example, maintaining an increased pressure may force hydrogen generated in the heated portion into a liquid phase (e.g. by dissolving). In addition, heating the portion to a temperature within a pyrolysis temperature range may pyrolyze at least some of the hydrocarbons within the formation to generate pyrolyzation fluids in the liquid phase. The generated components may include a double bond and/or a radical. H_2 in the liquid phase may reduce the double bond of the generated pyrolyzation fluids, thereby reducing a potential for polymerization of the generated pyrolyzation fluids. In addition, hydrogen may also neutralize radicals in the generated pyrolyzation fluids. Therefore, H_2 in the liquid phase may substantially inhibit the generated pyrolyzation fluids from reacting with each other and/or with other compounds in the formation. In this manner, shorter chain hydrocarbons may enter the vapor phase and may be produced from the formation.

Increasing the formation pressure to increase the amount of pyrolyzation fluids in the vapor phase may significantly reduce the potential for coking within the selected section of the formation. A coking reaction may occur in the liquid phase. Since many of the generated components may be transformed into short chain hydrocarbons and may enter the vapor phase, coking within the selected section may decrease.

Increasing the formation pressure to increase the amount of pyrolyzation fluids in the vapor phase is also beneficial because doing so permits increased recovery of lighter (and relatively high quality) pyrolyzation fluids. In general, pyrolyzation fluids are more quickly produced, with less residuals, when such fluids are in the vapor phase rather than in the liquid phase. Undesirable polymerization reactions also tend to occur more frequently when the pyrolyzation fluids are in the liquid phase instead of the vapor phase. In addition, when pyrolyzation fluids are produced in the vapor phase, fewer production wells/area are needed, thereby reducing project costs. (Specification, p. 119, line 18 through p. 120, line 20).

Thus, Applicant submits that controlling and/or altering the pressure or heat as recited in claims 560 and 566 are not obvious matters of choice or design. Applicant respectfully requests removal of the rejections of claims 560 and 566.

H. The Claims Are Not Obvious Over Ljungstrom In View of Tsai Pursuant To 35 U.S.C. 103(a)

The Examiner rejected claims 554, 558, and 559 under 35 U.S.C. 103(a) as obvious over Ljungstrom, "as applied to claim 531", and further in view of U.S. Patent No. 4,299,285 to Tsai et al. (hereinafter "Tsai"). Applicant respectfully disagrees with these rejections.

The Examiner states:

> While Ljungstrom does not disclose the presence of hydrogen in the coal heating production effluent, Tsai et al (col. 5, line 52- col. 6, line 15) clearly discloses that gasification/volatilization products resulting from heating and/or gasifying a coal formation include hydrogen.
>
> Accordingly, it is deemed that the volatilized/gasified coal production effluent produced in the process of Ljungstrom will obviously include a hydrogen component, as taught by Tsai et al, with the precise amount of hydrogen present, as called for in claims 554, 558, deemed an obvious expedient or matter of choice to one of ordinary skill in the art to which the invention pertains, based on, e.g., the actual intended use of the production effluent, such as a feed stream to a synthetic natural gas production facility or as process heat gas, as called for in claims.

Tsai states: "The net result is a combustible product gas comprising carbon monoxide, hydrogen and some methane as its principal combustibles...." (Tsai, col. 5, line 55 – col. 6, line 1) Applicant submits that the Examiner's statement "that the effluent produced in the process of Ljungstrom will obviously include a hydrogen component ... with the precise amount of hydrogen present as called for in claims 554, 558...." is extending the teaching of Tsai.

Amended claim 554 describes a combination of features including: "wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure, and wherein the molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure." Applicant submits that the combination of the cited art does not appear to teach or suggest the

range of molecular hydrogen content by volume percent recited in claim 554. Applicant respectfully requests removal of the rejection of claim 554.

Amended claim 558 describes a combination of features including: "controlling formation conditions to produce a mixture of condensable hydrocarbons and H_2, wherein a partial pressure of H_2 in the mixture is greater than about 0.5 bar." Applicant submits that the combination of the cited art does not appear to teach or suggest controlling formation conditions to produce a mixture from the formation, wherein a partial pressure of H_2 in the mixture is greater than about 0.5 bar. Applicant respectfully requests removal of the rejection of claim 558.

I. The Claims Are Not Obvious Over Ljungstrom In View of Justheim Pursuant To 35 U.S.C. 103(a)

The Examiner rejected claims 554, 558, 559, 561, and 562 under 35 U.S.C. 103(a) as obvious over Ljungstrom, "as applied to claim 531," and further in view of U.S. Patent No. 3,766,982 to Justheim (hereinafter "Justheim"). Applicant respectfully disagrees with these rejections.

The Examiner states:

> Justheim '982 injects hydrogen into the heated coal formation to hydrogenate the volatilized/pyrolyzed hydrocarbons evolved; and the hydrogen provided may further be obtained from production fluids obtained from the coal formation (col. 3, lines 1-9)
>
> Accordingly, it would have been obvious to one of ordinary skill in the art to which the invention pertains, to similarly inject hydrogen into the heated coal formation in the process of Ljungstrom, e.g., in the vicinity of the recovery wellbores, and provide the hydrogen from the production effluent, as taught by Justheim, in order to effect a partial hydroconversion/hydrotreating of the volatilized, pyrolyzed and/or gasified hydrocarbons prior to production in order to render the production effluent more suitable for further refining or above-ground processing/conversion, as called for in claims 561, 562.

Justheim states:

> Optimum temperature to be maintained in the hydrogenation zone is between about 1,050°F. and 1,250°F., the higher temperatures between 1,200°F. and 1,250°F. favoring hydrogasification of the surrounding shale to yield greater mobility to the kerogen vapor product. (Justheim, col. 2, lines 63-67)

Ljungstrom states:

> The second step (combustion) will usually be at a temperature above that of oil vaporization, for example about 300° C. and may be as high as desired but below that of decomposition of valuable products beyond the thermal and oxidation degree desired. A desirable range will usually be between about 300° C. and 550° C., and more desirably between 300 and 400° C. (Ljungstrom, col. 2, lines 34-41)

Amended claim 554 describes a combination of features including: "wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure, and wherein the molecular hydrogen is less than about 80 % by volume on the non-condensable component at 25 °C and one atmosphere absolute pressure." Amended claim 558 describes a combination of features including: "wherein a partial pressure of H_2 in the mixture is greater than about 0.5 bar."

Applicant submits that the Examiner is extending the teaching of Justheim in the rejections of claims 558 and 558 to include a specific content of a component in a produced mixture (e.g., a partial pressure of H_2 in the mixture greater than about 0.5 bar; greater than about 10 % by volume and less than about 80% by volume of the non-condensable component.) Applicant submits that the combination of the cited art does not appear to teach or suggest achieving a specific content of hydrogen in a produced mixture. Applicant respectfully requests removal of the rejections of claim 554 and 558.

J. Conclusion

Applicant submits that all claims are in condition for allowance. Favorable reconsideration is respectfully requested.

It is believed that no fees are due in association with the filing of this and accompanying documents. If any extension of time is required, Applicant hereby requests the appropriate extension of time. If any fees are required, please charge those fees to Meyertons, Hood, Kivlin, Kowert & Goetzel, P.C. Deposit Account Number 50-1505/5659-09600/EBM.

Respectfully submitted,

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Date: APRIL 30, 2003

Marked-Up Version Of Amendments Submitted With

Amendment; Response to Office Action Mailed January 31, 2003

In the Specification:

On page 123, the paragraph beginning on line 25:

The determined values for the parameter *A*, and the parameter *B*, may be used to determine an average pressure in the selected section of the formation using an assessed average temperature, *T*, in the selected section. The assessed average temperature may be determined as described herein. For example, an average pressure of the selected section may be determined by the relationship: $p = exp[(A/T) + B]$, in which *p* is measured in psia, and *T* is measured in degrees Kelvin. In an embodiment, an API gravity of the produced mixture may be controlled to be greater than about 25°, 30°, or 35° API by controlling average pressure and average temperature in the part of the formation such that the average pressure in the part of the formation is greater than *p* for an assessed average temperature *T* in the part of the formation when *A* = -44,000 and *B* = 67, *A* = -31,000 and *B* = 51, or *A* = -22,000 and *B* = 38, respectively. In an embodiment, a weight percentage of olefins in the produced mixture may be controlled to be less than about 20 % by weight, less than about 10 % by weight, or less than about 5 % by weight by controlling average pressure and average temperature in the part of the formation such that the average pressure in the part of the formation is greater than *p* for an assessed average temperature *T* in the part of the formation when *A* = -57,000 and *B* = 83, *A* = -16,000 and *B* = 28, or *A* = -12,000 and *B* = 22, respectively. In an embodiment, hydrocarbons having carbon numbers greater than 25 in the produced mixture may be controlled to be less than about 25 % by weight, less than about 20 % by weight, or less than about 15 % by weight by controlling average pressure and average temperature in the part of the formation such that the average pressure in the part of the formation is greater than *p* for an assessed average temperature *T* in the part of the formation when *A* = -14,000 and *B* = 25, *A* = -16,000 and *B* = 28, or *A* = -18,000 and *B* = 32, respectively. In an embodiment, an atomic hydrogen to carbon ratio in the produced mixture may be controlled to be greater than about 1.7, greater than about 1.8, or greater than about 1.9 by controlling average pressure and average temperature in the part of the formation

such that the average pressure in the part of the formation is greater than p for an assessed average temperature T in the part of the formation when A = -38,000 and B = 61, A = -13,000 and B = 24, or A = -8,000 and B = 18, respectively. Alternatively, an average absolute pressure of the selected section, measured in bars, may be determined using the following relationship: $p_{bars} = \exp[(A/T) + B - 2.6744]$. In this manner, an average pressure within the selected section may be controlled such that an average pressure within the selected section is adjusted to the average pressure as determined above, in order to produce a formation fluid from the selected section having a selected property.

In the Claims:

531. (amended) A method of treating a coal formation in situ, comprising:

providing heat from one or more heaters to at least a portion of the formation;

allowing the heat to transfer from the one or more heaters to a part of the formation;

controlling a pressure and a temperature ~~within~~ in at least a majority of the part of the formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure;

maintaining the controlled pressure of at least about 2.0 bars absolute; and

producing a mixture from the formation.

532. (amended) The method of claim 531, wherein the one or more heaters comprise at least two heaters, and wherein controlled superposition of heat from at least the two heaters pyrolyzes at least some hydrocarbons ~~within~~ in the part of the formation.

533. (amended) The method of claim 531, further comprising controlling formation conditions, wherein controlling formation conditions comprises maintaining a temperature ~~within~~ in the part of the formation ~~within~~ in a pyrolysis temperature range of about 270 °C to about 400 °C.

534. (amended) The method of claim 531, wherein at least one of the ~~one or more~~ heaters comprises an electrical heater.

535. (amended) The method of claim 531, wherein at least one of the ~~one or more~~ heaters comprises a surface burner.

536. (amended) The method of claim 531, wherein at least one of the ~~one or more~~ heaters comprises a flameless distributed combustor.

537. (amended) The method of claim 531, wherein at least one of the ~~one or more~~ heaters comprises a natural distributed combustor.

539. (amended) The method of claim 531, wherein providing heat from the one or more heaters to at least the portion of the formation comprises:

heating a selected volume (V) of the coal formation from the one or more heaters, wherein the formation has an average heat capacity (Cv), and wherein the heating pyrolyzes at least some hydrocarbons ~~within~~ in the selected volume of the formation; and

wherein heating energy/day (Pwr) provided to the selected volume is equal to or less than $h*V*C_v*\rho_B$, wherein ρ_B is formation bulk density, and wherein an average heating rate (h) of the selected volume is about 10 °C/day.

541. (amended) The method of claim 531, wherein ~~providing~~ allowing the heat to transfer from the one or more heaters ~~comprises heating the part of the formation such that~~ increases a thermal conductivity of at least a portion of the part of the formation ~~is~~ to greater than about 0.5 W/(m °C).

554. (amended) The method of claim 531, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure, and wherein the

molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure.

558. (amended) The method of claim 531, further comprising controlling formation conditions to produce a mixture of condensable hydrocarbons and H_2, wherein a partial pressure of H_2 ~~within~~ in the mixture is greater than about 0.5 bar.

560. (amended) The method of claim 531, further comprising altering a pressure ~~within~~ in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than about 25.

562. (amended) The method of claim 531, further comprising:

providing hydrogen (H_2) to the part of the formation to hydrogenate hydrocarbons ~~within~~ in the part of the formation; and

heating a portion of the part of the formation with heat from hydrogenation.

564. (amended) The method of claim 531, wherein allowing the heat to transfer ~~comprises increasing~~ increases a permeability of a majority of the part of the formation to greater than about 100 millidarcy.

565. (amended) The method of claim 531, wherein allowing the heat to transfer ~~comprises substantially uniformly increasing~~ increases a permeability of a majority of the part of the formation such that the permeability of the majority of the part of the formation is substantially uniform.

568. (amended) The method of claim 531, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein ~~three or more of~~ the heaters are located in the formation in a unit of heaters, and wherein the unit of heaters comprises a triangular pattern.

569. (amended) The method of claim 531, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein ~~three or more of~~ the heaters are located in the formation in a unit of heaters, wherein the unit of heaters comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

570. (amended) A method of treating a coal formation in situ, comprising:

providing heat from one or more heaters to at least a portion of the formation;

allowing the heat to transfer from the one or more heaters to a part of the formation to raise an average temperature ~~within~~in the part of the formation to, or above, a temperature that will pyrolyze hydrocarbons ~~within~~in the part of the formation;

producing a mixture from the formation; and

controlling API gravity of the produced mixture to be greater than about 25 degrees API by controlling average pressure and average temperature in the part of the formation such that the average pressure in the part of the formation is greater than the pressure (p) set forth in the following equation for an assessed average temperature (T) in the part of the formation:

$$p = e^{[-44000/T + 67]}$$

where p is measured in psia and T is measured in Kelvin.

573. (amended) The method of claim 570, wherein the one or more heaters comprise at least two heaters, and wherein superposition of heat from at least the two heaters pyrolyzes at least some hydrocarbons ~~within~~in the part of the formation.

574. (amended) The method of claim 570, wherein controlling the average temperature comprises maintaining a temperature in the part of the formation ~~within~~in a pyrolysis temperature range of about 270 °C to about 400 °C.

575. (amended) The method of claim 570, wherein at least one of the ~~one or more~~ heaters comprises an electrical heater.

576. (amended) The method of claim 570, wherein at least one of the ~~one or more~~ heaters comprises a surface burner.

577. (amended) The method of claim 570, wherein at least one of the ~~one or more~~ heaters comprises a flameless distributed combustor.

578. (amended) The method of claim 570, wherein at least one of the ~~one or more~~ heaters comprises a natural distributed combustor.

579. (amended) The method of claim 570, further comprising controlling a temperature ~~within~~in at least a majority of the part of the formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

581. (amended) The method of claim 570, wherein providing heat from the one or more heaters to at least the portion of the formation comprises:

heating a selected volume (V) of the coal formation from the one or more heaters, wherein the formation has an average heat capacity (C_v), and wherein the heating pyrolyzes at least some hydrocarbons ~~within~~in the selected volume of the formation; and

wherein heating energy/day (Pwr) provided to the selected volume is equal to or less than $h*V*C_v*\rho_B$, wherein ρ_B is formation bulk density, and wherein an average heating rate (h) of the selected volume is about 10 °C/day.

583. (amended) The method of claim 570, wherein ~~providing heat~~allowing the heat to transfer from the one or more heaters ~~comprises heating the part of the formation such that~~increases a thermal conductivity of at least a portion of the part of the formation ~~is~~ to greater than about 0.5 W/(m °C).

595. (amended) The method of claim 570, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure, and wherein the

molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure.

598. (amended) The method of claim 570, further comprising controlling formation conditions to produce a mixture of condensable hydrocarbons and H_2, wherein a partial pressure of H_2 ~~within~~in the mixture is greater than about 0.5 bar.

600. (amended) The method of claim 570, further comprising altering a pressure ~~within~~in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than about 25.

602. (amended) The method of claim 570, further comprising:

providing hydrogen (H_2) to the part of the formation to hydrogenate hydrocarbons ~~within~~in the part of the formation; and

heating a portion of the part of the formation with heat from hydrogenation.

604. (amended) The method of claim 570, wherein allowing the heat to transfer ~~comprises increasing~~increases a permeability of a majority of the part of the formation to greater than about 100 millidarcy.

605. (amended) The method of claim 570, wherein allowing the heat to transfer ~~comprises substantially uniformly increasing~~increases a permeability of a majority of the part of the formation such that the permeability of the majority of the part of the formation is substantially uniform.

608. (amended) The method of claim 570, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein ~~three or more of~~ the heaters are located in the formation in a unit of heaters, and wherein the unit of heaters comprises a triangular pattern.

609. (amended) The method of claim 570, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein ~~three or more of~~ the heaters are located in the formation in a unit of heaters, wherein the unit of heaters comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

610. (amended) A method of treating a coal formation in situ, comprising:

providing heat to at least a portion of a coal formation such that a temperature (T) in a substantial part of the heated portion exceeds 270 °C and hydrocarbons are pyrolyzed ~~within~~in the heated portion of the formation;

controlling a pressure (p) ~~within~~in at least a substantial part of the heated portion of the formation;

wherein $p_{bar} > e^{[(-A/T)+B-2.6744]}$;

wherein p is the pressure in bar absolute and T is the temperature in Kelvin, and A and B are parameters that are larger than 10 and are selected in relation to the characteristics and composition of the coal formation and on the required olefin content and carbon number of the pyrolyzed hydrocarbon fluids; and

producing pyrolyzed hydrocarbon fluids from the heated portion of the formation.

623. (amended) A method of treating a coal formation in situ, comprising:

providing heat from one or more heaters to at least a portion of the formation;

allowing the heat to transfer from the one or more heaters to a part of the formation to raise an average temperature ~~within~~in the part of the formation to, or above, a temperature that will pyrolyze hydrocarbons ~~within~~in the part of the formation;

producing a mixture from the formation; and

controlling a weight percentage of olefins of the produced mixture to be less than about 20 % by weight by controlling average pressure and average temperature in the part of the formation such that the average pressure in the part of the formation is greater than the pressure (p) set forth in the following equation for an assessed average temperature (T) in the part of the formation:

$$p = e^{[-57000/T + 83]}$$

where p is measured in psia and T is measured in Kelvin.

665. (amended) A method of treating a coal formation in situ, comprising:

providing heat from one or more heaters to at least a portion of the formation;

allowing the heat to transfer from the one or more heaters to a part of the formation to raise an average temperature ~~within~~in the part of the formation to, or above, a temperature that will pyrolyze hydrocarbons ~~within~~in the part of the formation;

producing a mixture from the formation; and

controlling hydrocarbons having carbon numbers greater than 25 of the produced mixture to be less than about 25 % by weight by controlling average pressure and average temperature in the part of the formation such that the average pressure in the part of the formation is greater than the pressure (p) set forth in the following equation for an assessed average temperature (T) in the part of the formation:

$$p = e^{[-14000/T + 25]}$$

where p is measured in psia and T is measured in Kelvin.

666. (amended) The method of claim 665, wherein the hydrocarbons having carbon numbers greater than 25 of the produced mixture ~~is~~ are controlled to be less than about 20 % by weight, and wherein the equation is:

$$p = e^{[-16000/T + 28]}.$$

667. (amended) The method of claim 665, wherein the hydrocarbons having carbon numbers greater than 25 of the produced mixture ~~is~~ are controlled to be less than about 15 % by weight, and wherein the equation is:

$$p = e^{[-18000/T + 32]}.$$

668. (amended) The method of claim 665, wherein the one or more heaters comprise at least two heaters, and wherein superposition of heat from at least the two heaters pyrolyzes at least some hydrocarbons ~~within~~in the part of the formation.

669. (amended) The method of claim 665, wherein at least one of the ~~one or more~~ heaters comprises an electrical heater.

670. (amended) The method of claim 665, wherein at least one of the ~~one or more~~ heaters comprises a surface burner.

671. (amended) The method of claim 665, wherein at least one of the ~~one or more~~ heaters comprises a flameless distributed combustor.

672. (amended) The method of claim 665, wherein at least one of the ~~one or more~~ heaters comprises a natural distributed combustor.

673. (amended) The method of claim 665, further comprising controlling a temperature ~~within~~in at least a majority of the part of the formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

674. (amended) The method of claim 673, wherein controlling the temperature comprises maintaining a temperature ~~within~~in the part of the formation ~~within~~in a pyrolysis temperature range of about 270 °C to about 400 °C.

676. (amended) The method of claim 665, wherein providing heat from the one or more heaters to at least the portion of the formation comprises:

heating a selected volume (V) of the coal formation from the one or more heaters, wherein the formation has an average heat capacity (C_v), and wherein the heating pyrolyzes at least some hydrocarbons ~~within~~in the selected volume of the formation; and

wherein heating energy/day (Pwr) provided to the selected volume is equal to or less than $h*V*C_v*\rho_B$, wherein ρ_B is formation bulk density, and wherein an average heating rate (h) of the selected volume is about 10 °C/day.

678. (amended) The method of claim 665, wherein ~~providing heat~~allowing the heat to transfer from the one or more heaters ~~comprises heating the part of the formation such that~~increases a

thermal conductivity of at least a portion of the part of the formation ~~is~~ to greater than about 0.5 W/(m °C).

690. (amended) The method of claim 665, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure, and wherein the molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure.

693. (amended) The method of claim 665, further comprising controlling formation conditions to produce a mixture of condensable hydrocarbons and H_2, wherein a partial pressure of H_2 ~~within~~in the mixture is greater than about 0.5 bar.

695. (amended) The method of claim 665, further comprising altering a pressure ~~within~~in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than about 25.

696. (amended) The method of claim 665, further comprising:

providing hydrogen (H_2) to the part of the formation to hydrogenate hydrocarbons ~~within~~in the part of the formation; and

heating a portion of the part of the formation with heat from hydrogenation.

698. (amended) The method of claim 665, wherein allowing the heat to transfer ~~comprises increasing~~increases a permeability of a majority of the part of the formation to greater than about 100 millidarcy.

702. (amended) The method of claim 665, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein three or more of the heaters are located in the formation in a unit of heaters, and wherein the unit of heaters comprises a triangular pattern.

703. (amended) The method of claim 665, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein ~~three or more of~~ the heaters are located in the formation in a unit of heaters, wherein the unit of heaters comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

704. (amended) A method of treating a coal formation in situ, comprising:

providing heat from one or more heaters to at least a portion of the formation;

allowing the heat to transfer from the one or more heaters to a part of the formation to raise an average temperature ~~within~~in the part of the formation to, or above, a temperature that will pyrolyze hydrocarbons ~~within~~in the part of the formation;

producing a mixture from the formation; and

controlling an atomic hydrogen to carbon ratio of the produced mixture to be greater than about 1.7 by controlling average pressure and average temperature in the part of the formation such that the average pressure in the part of the formation is greater than the pressure (p) set forth in the following equation for an assessed average temperature (T) in the part of the formation:

$$p = e^{[-38000/T + 61]}$$

where p is measured in psia and T is measured in Kelvin.

5150. (amended) The method of claim 623, wherein the one or more heaters comprise at least two heaters, and wherein superposition of heat from at least the two heaters pyrolyzes at least some hydrocarbons ~~within~~in the part of the formation.

5151. (amended) The method of claim 623, wherein at least one of the ~~one or more~~ heaters comprises an electrical heater.

5152. (amended) The method of claim 623, wherein at least one of the ~~one or more~~ heaters comprises a surface burner.

5153. (amended) The method of claim 623, wherein at least one of the ~~one or more~~ heaters comprises a flameless distributed combustor.

5154. (amended) The method of claim 623, wherein at least one of the ~~one or more~~ heaters comprises a natural distributed combustor.

5155. (amended) The method of claim 704, wherein the one or more heaters comprise at least two heaters, and wherein superposition of heat from at least the two heaters pyrolyzes at least some hydrocarbons ~~within~~in the part of the formation.

5156. (amended) The method of claim 704, wherein at least one of the ~~one or more~~ heaters comprises an electrical heater.

5157. (amended) The method of claim 704, wherein at least one of the ~~one or more~~ heaters comprises a surface burner.

5158. (amended) The method of claim 704, wherein at least one of the ~~one or more~~ heaters comprises a flameless distributed combustor.

5159. (amended) The method of claim 704, wherein at least one of the ~~one or more~~ heaters comprises a natural distributed combustor.

5160. (amended) The method of claim 704, further comprising controlling a temperature ~~within~~in at least a majority of the part of the formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure.

5161. (amended) The method of claim 5155, wherein controlling the temperature comprises maintaining a temperature ~~within~~in the part of the formation ~~within~~in a pyrolysis temperature range of about 270 °C to about 400 °C.

5163. (amended) The method of claim 704, wherein providing heat from the one or more heaters to at least the portion of the formation comprises:

heating a selected volume (V) of the coal formation from the one or more heaters, wherein the formation has an average heat capacity (C_v), and wherein the heating pyrolyzes at least some hydrocarbons ~~within~~in the selected volume of the formation; and

wherein heating energy/day (Pwr) provided to the selected volume is equal to or less than $h*V*C_v*\rho_B$, wherein ρ_B is formation bulk density, and wherein an average heating rate (h) of the selected volume is about 10 °C/day.

5165. (amended) The method of claim 704, wherein ~~providing heat~~ allowing the heat to transfer from the one or more heaters ~~comprises heating the part of the formation such that~~increases a thermal conductivity of at least a portion of the part of the formation ~~is~~ to greater than about 0.5 W/(m °C).

5177. (amended) The method of claim 704, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure, and wherein the molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure.

5180. (amended) The method of claim 704, further comprising controlling formation conditions to produce a mixture of condensable hydrocarbons and H_2, wherein a partial pressure of H_2 ~~within~~in the mixture is greater than about 0.5 bar.

5182. (amended) The method of claim 704, further comprising altering a pressure ~~within~~in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than about 25.

5183. (amended) The method of claim 704, further comprising:

providing hydrogen (H_2) to the part of the formation to hydrogenate hydrocarbons ~~within~~in the part of the formation; and

heating a portion of the part of the formation with heat from hydrogenation.

5185. (amended) The method of claim 704, wherein allowing the heat to transfer ~~comprises increasing~~increases a permeability of a majority of the part of the formation to greater than about 100 millidarcy.

5186. (amended) The method of claim 704, wherein allowing the heat to transfer ~~comprises substantially uniformly increasing~~increases a permeability of a majority of the part of the formation such that the permeability of the majority of the part of the formation is substantially uniform.

5189. (amended) The method of claim 704, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein ~~three or more of~~ the heaters are located in the formation in a unit of heaters, and wherein the unit of heaters comprises a triangular pattern.

5190. (amended) The method of claim 704, further comprising providing heat from ~~three or more~~ heaters to at least a portion of the formation, wherein ~~three or more of~~ the heaters are located in the formation in a unit of heaters, wherein the unit of heaters comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.